Porous Carbonate Buildup Play

(USGS Designation 2102, 2201)

General Characteristics

The Porous Carbonate Buildup Play in the Paradox and San Juan Basin Provinces (Fig. UM-11) is primarily a gas play and is characterized by oil and gas accumulations in mounds of algal (Ivanovia) limestone associated with organic-rich black shale rimming the evaporite sequences of the Paradox Formation of the Hermosa Group (Fig. UM-12). Most developed fields within the play produce from combination traps in the Paradox Basin Province.

Reservoirs: Almost all hydrocarbon production has been from vuggy limestone and dolomite reservoirs in five zones of the Hermosa Group. In ascending order they are the Alkali Gulch, Barker Creek, Akah, Desert Creek, and Ismay Stages (Fig. UM-13). The zones gradually become less distinct toward the central part of the San Juan Basin. Net pay thicknesses generally range from 10 to 50 feet and have porosities of 5-20 percent.

Source rocks: Source beds for Pennsylvanian oil and gas are believed to be organic-rich shales and laterally equivalent carbonate rocks within the Paradox Formation. The presence of hydrogen sulfide (H_2S) and appreciable amounts of CO_2 at the Barker Creek and Ute Dome fields probably indicates high-temperature decomposition of carbonates, (Rice, 1983). Correlation of black dolomitic shale and mudstone units of the Paradox Formation with prodelta facies in clastic cycles present in a proposed fan delta complex on the northeastern edge of the Paradox Evaporite Basin helps to account for the high percentage of kerogen from terrestrial plant material in black shale source rocks.

Timing and migration: In the central part of the San Juan Basin, Pennsylvanian sediments entered the thermal zone of oil generation during the Late Cretaceous to Paleocene, and the dry gas zone during the Eocene to Oligocene. It also is probable that Pennsylvanian source rocks entered the zone of oil generation during the Oligocene throughout most of the Four Corners Platform. Updip migration and local migration from laterally equivalent carbonates and shale beds in areas of favorable reservoir beds predominate, and remigration may have occurred in areas of faulting and fracturing.

Traps: Combination stratigraphic and structural trapping mechanisms are dominant among Pennsylvanian fields of the San Juan Basin and Four Corners Platform. Most fields are located on structures, although not all of these structures demonstrate closure. The structures themselves may have been a critical factor in the deposition of bioclastic limestone reservoir rocks. Seals are provided by a variety of mechanisms, including porosity differences in the reservoir rock, overlying evaporites, and interbedded shales. Most production on the Four Corners Platform is from depths of 5,100 to 8,500 feet, but minor production and shows in the central part of the San Juan Basin are from as deep as 11,000 feet.

Exploration status and resource potential: Field sizes in the play vary considerably; most oil discoveries are in the 1–100 MMBO size range and include associated gas production. The largest fields, Tocito Dome and Tocito Dome North, have produced a total of about 13 MMBO and 26 BCFG. Eight significant nonassociated and associated gas fields have been developed in the play, the largest of which, Barker Creek, has produced 205 BCFG. The Pennsylvanian is basically a gas play and has a moderate future potential for medium-size fields.

Characteristics of Play

In the Ute Mountain Ute Indian Reservation the Paradox Formation is conformably bounded by the Pinkerton Trail Formation at its base and the Honaker Trail Formation at its top (Fig. UM-14). It ranges from 800 feet thick in the south to 1700 feet thick in the north (Fig. UM-14). The Paradox Formation was deposited during the Desmoinesian age of the Pennsylvanian Period under strong cyclic conditions involving transgressive and regressive movements of the Pennsylvanian sea. The transgressive phase is represented by black organic rich dolomitic muds while the regressive phase is represented by carbonate mounds. Reservoirs within the reservation are biogenic/bioclastic carbonate mounds deposited in shoaling areas of an evaporite basin. The four main cycles of Desmoinesian deposition are the Barker Creek, Akah, Desert Creek, and Ismay Stages (Fig. UM-13).

The Barker Creek Stage has a gross thickness of 500 feet. It is a fossiliferous, algal, dolomitic limestone with vuggy secondary dolomite. Most reservoir rock is algal, dolomitic limestone with enhanced porosity and permeability due to dolomitization and weathering. The Barker Creek was deposited on paleostructural features related to the Hogback Lineament.

The Akah Stage is not considered to be an exploration objective within the reservation because salt and anhydrite deposition was dominant during this stage. The Akah Stage represents the maximum extent of evaporite limits.

The Desert Creek Stage carbonates were deposited in a definable arcuate trend around the southeast terminus of the basin. The Desert Creek is bounded by the Chimney Rock and Gothic Shales which represent transgressions (Fig. UM-13). Growth of the Desert Creek carbonate bank occurred during slow subsidence of the Paradox Basin. Source rocks for hydrocarbons are the Chimney Rock and Gothic Shales.

The Ismay Stage is divided into lower and upper units. In the lower unit, bounded by the Gothic and Hovenweep Shales, oil is produced from algal carbonate mound buildups. The upper unit is bounded by the Hovenweep and Boundary Butte Shales. Production there is from algal or fossiliferous detrital bioclastic/biogenic reservoirs. The source rocks for the Ismay stage are the Gothic, Hovenweep, and Boundary Butte Shales. During the Ismay Stage the southern part of the basin was slowly subsiding.

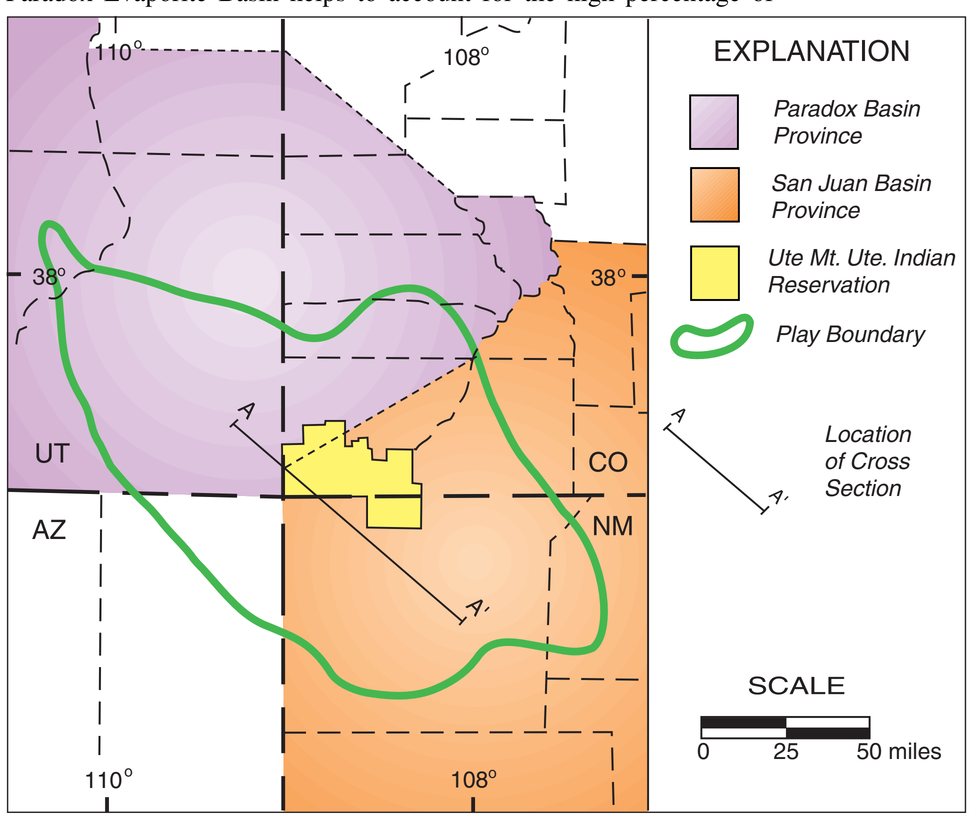

Figure UM-11. Location of Porous Carbonate Buildup Play (modified after Peterson, 1996).

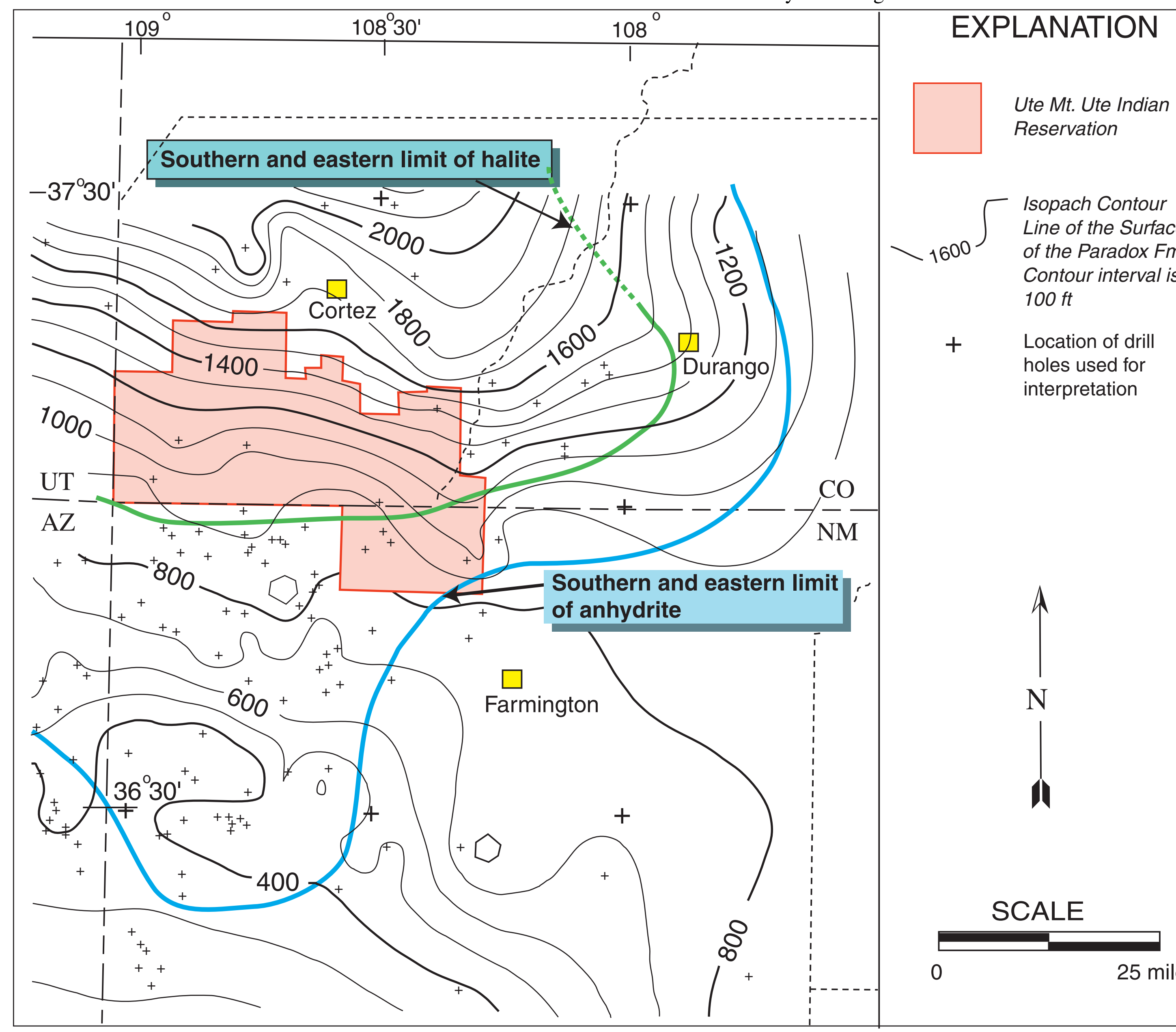

Figure UM-12. Isopach map of the Paradox Formation (modified after Huffman and Condon, 1993).

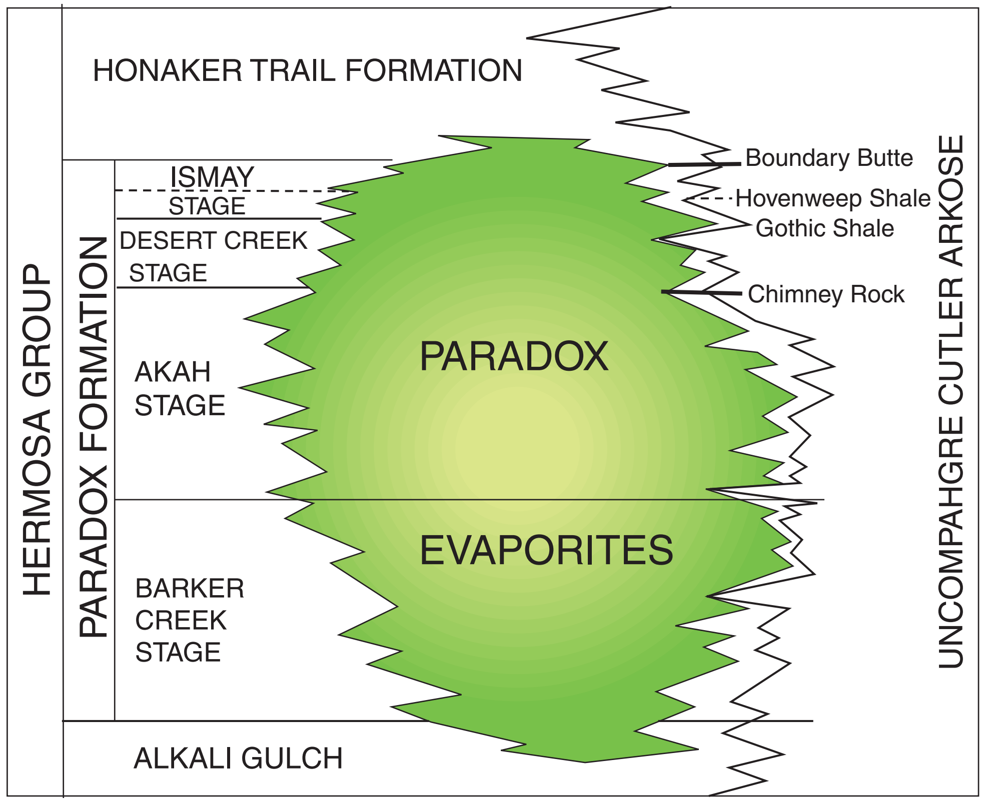

Figure UM-13. Stratigraphic chart of the Pennsylvanian Hermosa Group illustrating the Paradox facies change across the basin. Each stage is bounded by a time stratigraphic marker bed of sapropelic, dolomitic mud. These markers are continuous and mappable throughout the basin (modified from Harr, 1996).

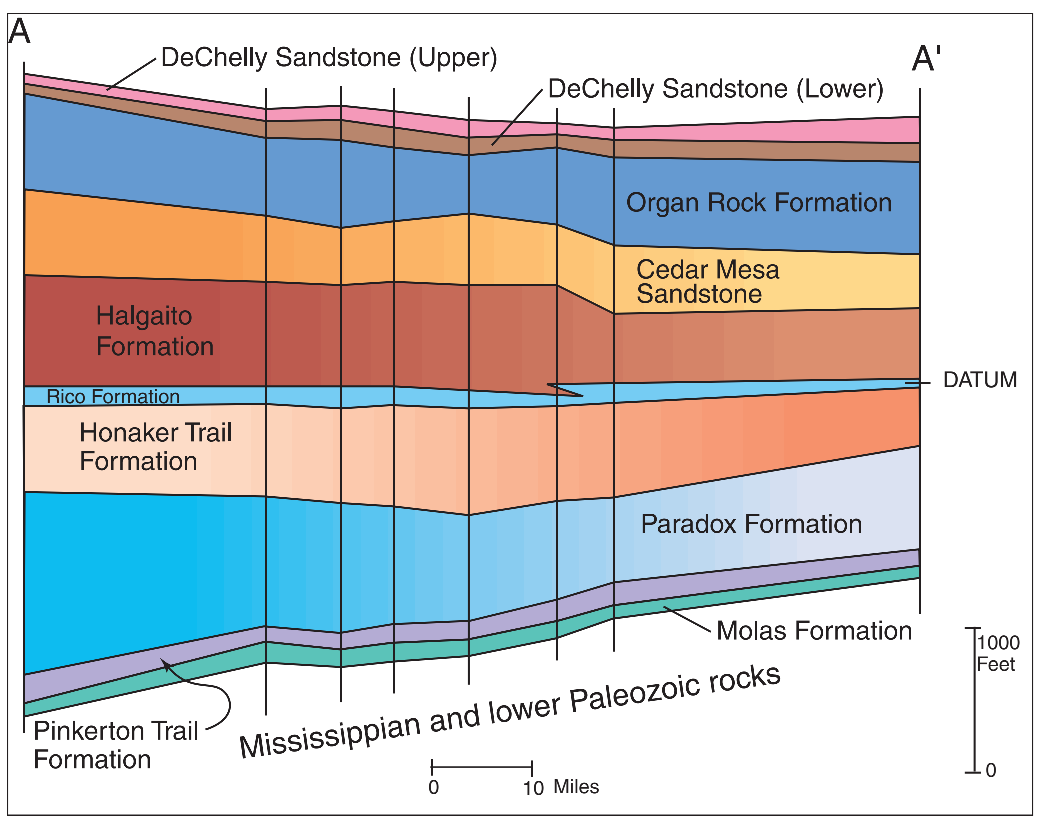

Figure UM-14. Stratigraphic cross section through Ute Mountain Ute Indian Reservation (modified from Huffman and Condon, 1993).

Analog Fields

Within or Near Reservation

(*) denotes field lies within the reservation boundaries

*Barker Creek Paradox Field (Fig. UM-15)

Location of discovery well: SE¼, SE¼, NW¼, Sec 21, T32N, R14W, NMPM (March, 1945)
Producing formation: Paradox Formation
Number of producing wells: 5 (1977)
Production: 215,279,080 MCFG (1996)
141,773 BO (1977)
Gas characteristics: BTU 777 (dry basis)
Type of drive: Solution gas, fluid expansion, ineffective bottom water encroachment
Average net pay: ± 100 feet
Porosity: 2-10%
Permeability: extremely variable

Heron North Field

Location of discovery well: NE ¼, NW ¼, sec. 35, T41N, R25W (1991)
Producing formation: Desert Creek Stage, Paradox Formation
Number of producing wells: 1
Production: 0.31 BCFG
200,759 BO (January 1, 1996)
Average net pay: 60 feet
Porosity: 15%
Permeability: 17.7 md

*Wickiup Field

Location of discovery well: SW ¼, SE ¼, Sec 24, T33N, R14W (March, 1972)
Producing formation: Barker Creek Stage, Paradox Formation
Number of producing wells: 1 (1983)
Production: 41,872 MCFG (1996)
Gas characteristics: BTU 914.
Type of drive: Gas Expansion
Average net pay: 10 feet
Porosity: 8%

*Ute Dome Paradox Field

Location of discovery well: NE ¼, NE ¼, Sec 35, T32N, R14W (September, 1948)
Producing formation: Barker Creek Stage, Paradox Formation
Number of producing wells: 11 (1977)
Production: 93,589,058 MCFG (1996)
Gas characteristics: BTU 777 (dry basis)
Type of drive: Primary Volumetric with limited water drive in Barker Creek Zone
Average net pay: 116 feet
Porosity: 3.5%
Permeability: 0.5 md (enhanced by fracturing)

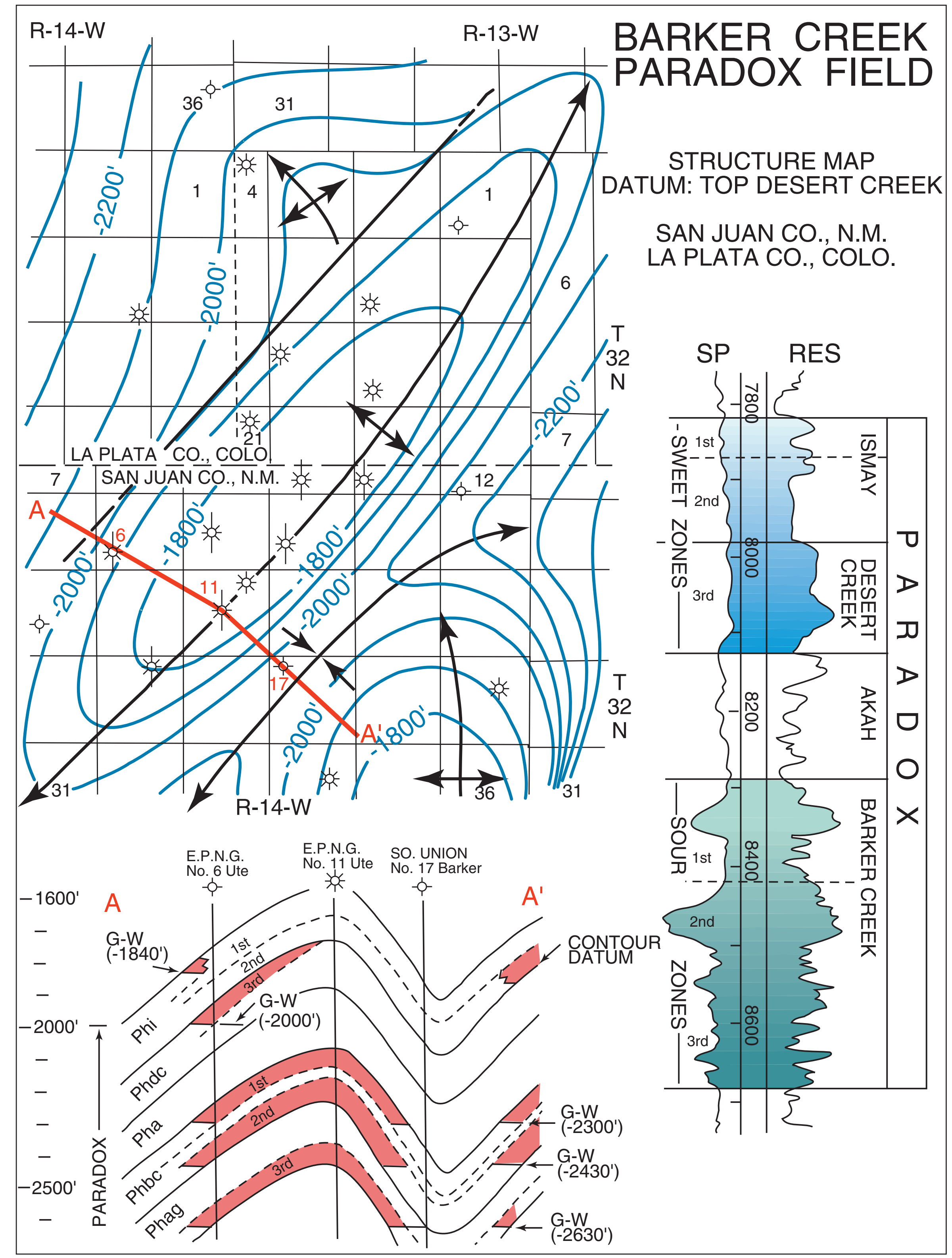

Figure UM-15. Structure contour map, type log, and cross section of Barker Creek Paradox Field (modified from Matheny, 1978).

Tocito-Gallup Sandstone Oil Play

(USGS Designation 2207)

General Characteristics

The Tocito-Gallup Sandstone Oil Play is an oil and associated gas play in lenticular sandstone bodies of the Upper Cretaceous Gallup Sandstone and Tocito Sandstone Lentil, associated with Mancos Shale source rocks lying immediately above an unconformity. The play covers almost the entire area of the province (Fig. UM-16). Most of the producing fields are stratigraphic traps along a north west- trending belt near the southern margin of the central part of the San Juan Basin. Almost all production has been from the Tocito Sandstone Lentil of the Mancos Shale and the Torrivio Member of the Gallup Sandstone. Locations of oil field discovery wells producing from the Tocito-Gallup Sandstone Oil Play are shown in figure UM-17.

Reservoirs: The Tocito Sandstone Lentil of the Mancos Shale is the major oil producing reservoir in the San Juan Basin. The name is applied to a number of lenticular sandstone bodies, commonly less than 50 feet thick, that lie on or just above an unconformity and are of undetermined origin. Reservoir porosities in producing fields range from 4 to 20 percent and average about 15 percent. Permeabilities range from 0.5 to 150 Md and are typically 5 - 100 Md. The only significant production from the regressive Gallup Sandstone is from the Torrivio Member, a lenticular fluvial channel sandstone lying above, and in some places scouring into the top of the main marine Gallup Sandstone.

Source rocks: Source beds for Gallup oil are found in the marine Upper Cretaceous Mancos Shale. The Mancos contains 1-3 weight percent organic carbon and produces a sweet, low-sulfur, paraffin-base oil that ranges from 38° to 43° API gravity in the Tocito fields and from 24°to 32° API gravity farther to the south in the Hospah and Hospah South fields.

Timing and migration: The Upper Mancos Shale of the central part of the San Juan Basin entered the thermal zone of oil generation in the late Eocene and gas generation in the Oligocene. Migration up dip to reservoirs in the Tocito Sandstone Lentil and regressive Gallup followed pathways similar to those determined by present structure because basin configuration has changed little since that time.

Traps: Almost all Gallup production is from stratigraphic traps at depths between 1,500 and 5,500 feet. Hospah and Hospah South, the largest fields in the regressive Gallup Sandstone, are combination stratigraphic and structural traps. The Tocito Sandstone is sealed by, encased in, and intertongues with the marine Mancos Shale, forming stratigraphic traps. Similarly, the fluvial channel Torrivio Member of the Gallup is encased in and intertongues with finer grained, organic-rich coastal-plain shales.

Exploration status and resource potential: Initial Gallup field discoveries were made in the mid 1920's, however the major discoveries were not made until the late 1950's and early 1960's in the deeper Tocito fields. The largest of these, Bisti, covers 37,500 acres and has estimated total ultimate recovery of 51 MMBO. Gallup producing fields are typically 1,000-10,000 acres in area and have 15-30 feet of pay. About one-third of these fields have an estimated cumulative production exceeding 1 MMBO and 1 BCF of associated gas. All of the larger fields produce from the Tocito Sandstone Lentil of the Mancos Shale and are stratigraphically controlled. South of the zone of sandstone buildups of the Tocito, the regressive Gallup Sandstone produces primarily from the fluvial channel sandstone of the Torrivio Member. The only large fields producing from the Torrivio are the Hospah and Hospah South fields, which are combination traps. Similar, undiscovered traps of small size may be present in the southern half of the basin. The future potential for oil and gas is low to moderate.

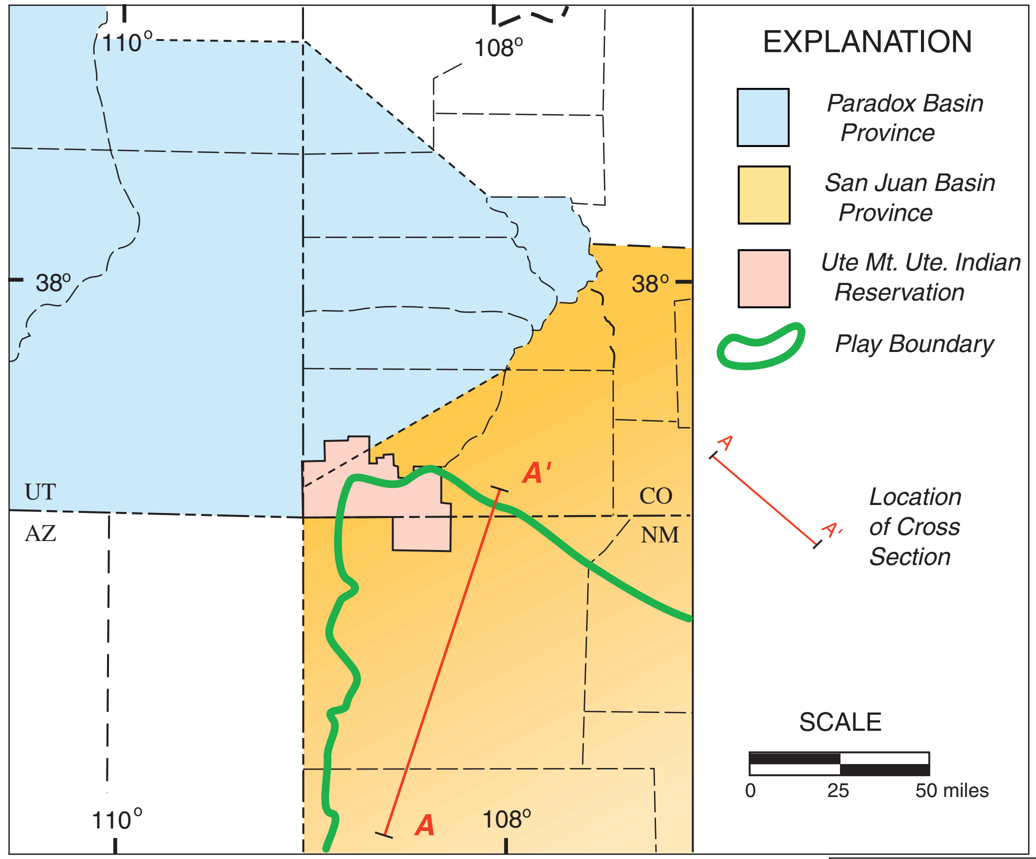

Figure UM-16. Location of the Tocito-Gallup Oil Play. Cross section A-A' is shown in Figure UM-18 (modified after Gautier, et al.,1996)

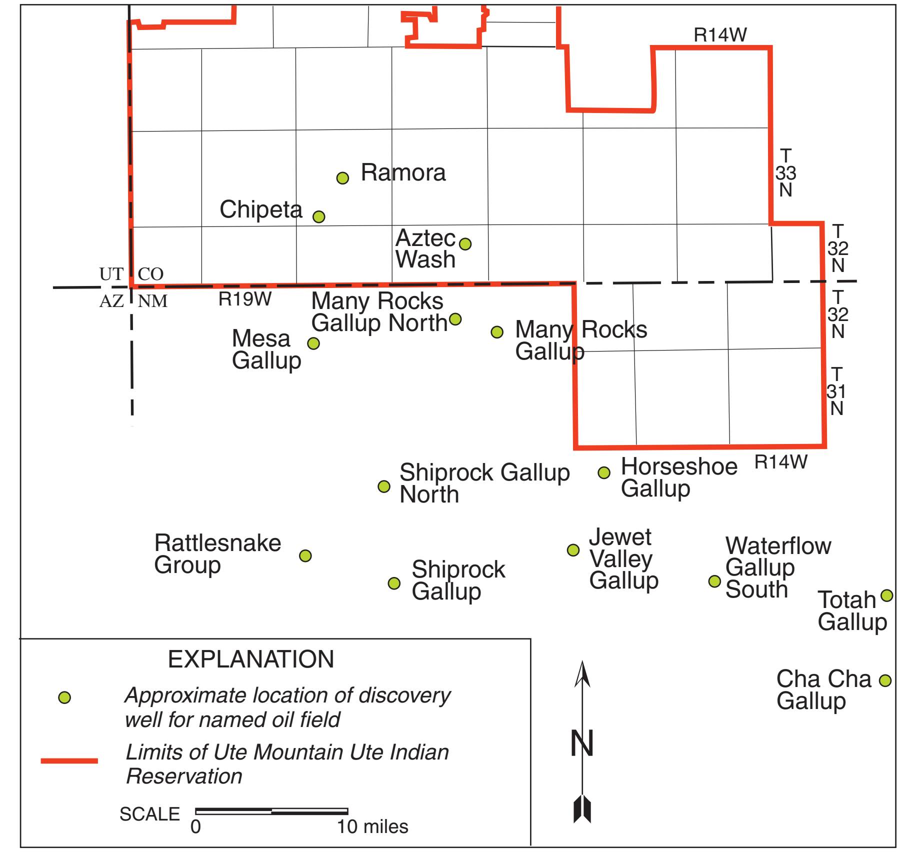

Figure UM-17. Location of oil field discovery wells for fields producing from the Tocito-Gallup Sandstone Oil Play.

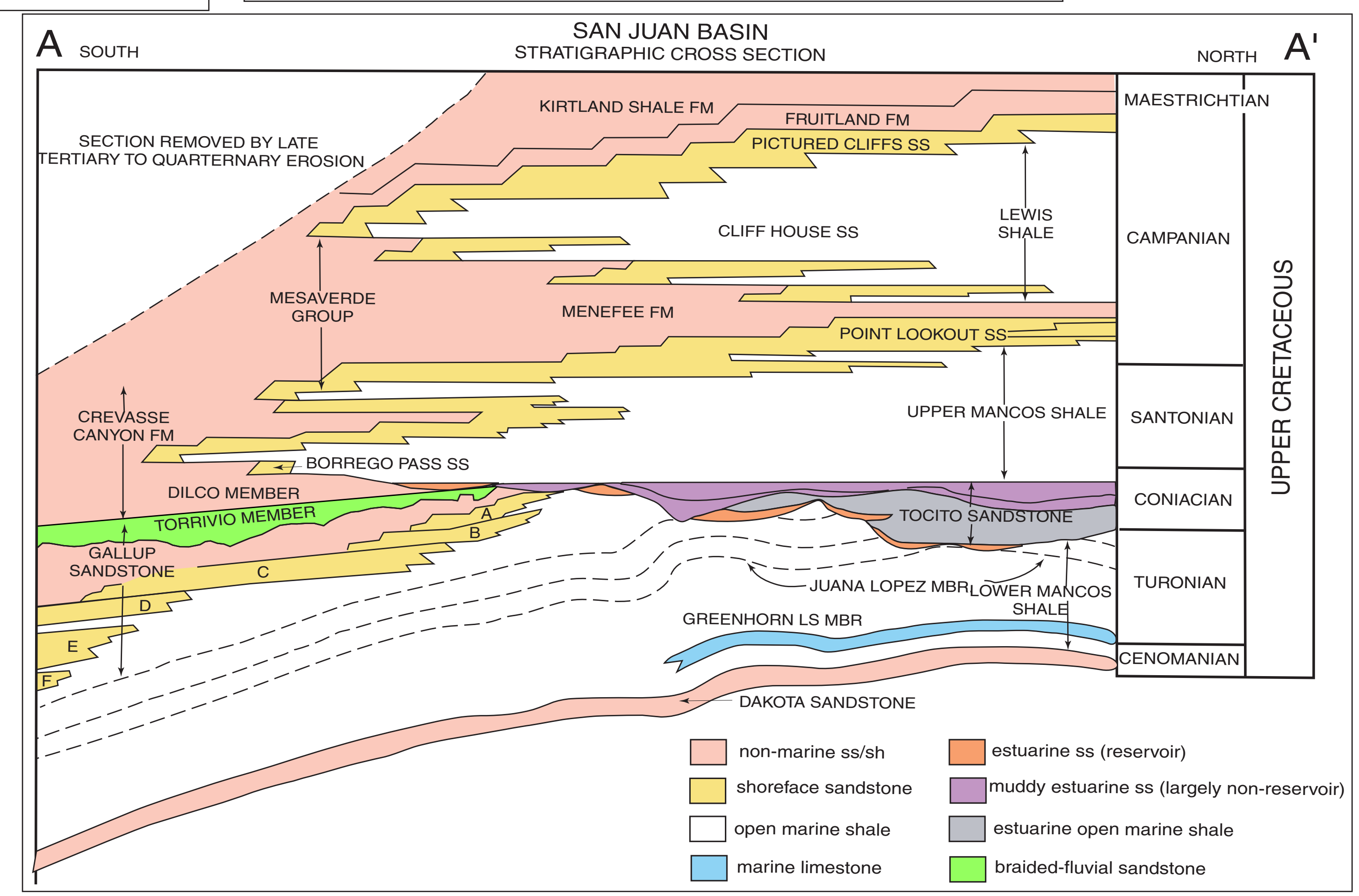

Figure UM-18. Schematic south to north cross-section of the Cretaceous stratigraphy in northwestern New Mexico with emphasis and detail on the late Turonian-Coniacian interval (modified after Molenaar, 1973, 1983a,b).

Characteristics of the Tocito-Gallup Oil Play

In recent years a sequence stratigraphic framework has been applied to the Tocito and Gallup Sandstones near the Ute Mountain Ute In dian Reservation (Jennett and Jones, 1995). This framework ex plains hydrocarbon occurrence and the stratigraphic traps associated with these units. The northern extent of the Gallup Sandstone pro duction is several miles south of the Indian reservation where it is truncated by the Tocito Sandstone (Fig. UM-18). For this reason the Gallup Sandstone will not be included in the following description.

Since the late 1950's, 130 MMBOE have been produced from the Tocito. The Tocito Sandstone marks a significant change from shoreface/coastal plain depositional systems which prevailed throughout Gallup deposition. The Tocito Sandstone is a transgres sive sequence set internally composed of four high- frequency se quences; in ascending order they are Tocito-1, Tocito-2, Tocito-3 and Tocito-4 (Fig. UM-19). In the subsurface, the Tocito is distributed into narrow and elongate bodies which trend northwest-southeast (Figs. UM-20 to UM-23).

The high-frequency sequences of the Tocito Sandstone contain the lowstand, transgressive, and usually highstand systems tracts. There are sequence boundaries at the base of each high-frequency se quence represented by irregular erosional surfaces that truncate into the underlying units. Above the erosional surfaces are incised valley fill deposits representing the lowstand systems tracts. The tops of the valley fills represent transgressive flooding surfaces, the passage from valley-filling sedimentation to open-marine/shelfal sedimenta tion, and the onset to the transgressive systems tracts. The transgres sive systems tracts are overlain by distal marine shales of the high stand systems tracts (Tocito-1 and Tocito-2 only). Due to their close vertical juxtaposition, the four Tocito sequences are collectively in terpreted as components of a sequence set. The four sequences are thought to reflect higher-order cycles in relative sea level which were superimposed on a longer term cycle.

Hydrocarbon trapping is the result of stratigraphic relationships. Structural dip is uniformly toward the northeast and consequently provides only minor influence on the pooling of hydrocarbons. The four main trapping elements are truncation by younger sequence boundaries, arcuate bends in valleys, up-dip valley termination, and structural closure (Fig. UM-24).

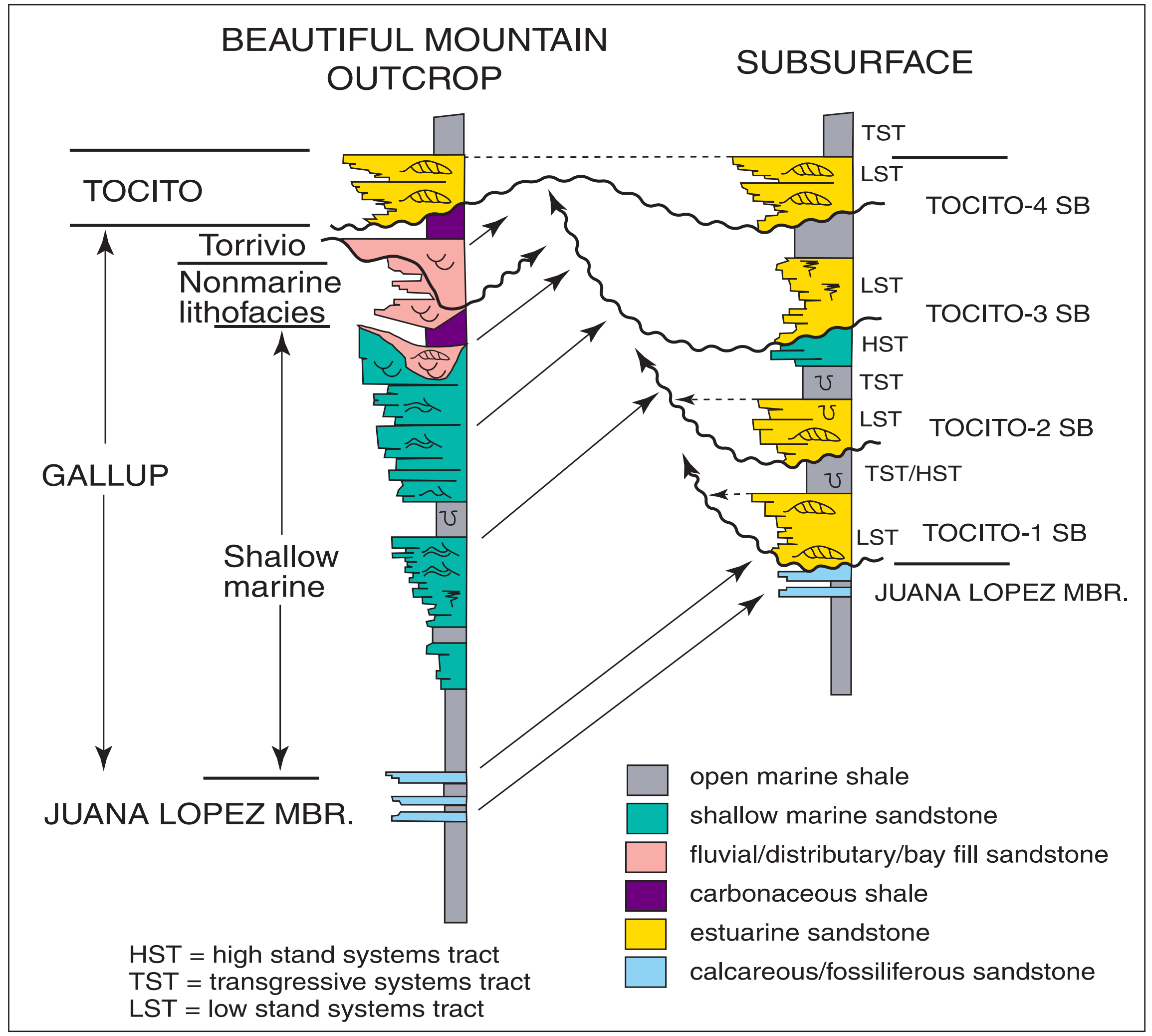

Figure UM-19. Composite stratigraphic summary comparing the outcrop of the Gallup and Tocito interval. Along Beautiful Mountain, a relatively complete Gallup section from the Juana Lopez to the Torrivio Sandstone occurs beneath the Tocito Sandstone Lentil. To the north in the subsurface, four sequences compromise the Tocito interval, with the lowermost sequence boundary erosionally resting on beds of the Juana Lopez Member. The missing section is close to 400 feet. The sequence boundaries merge toward the outcrop and form a composite surface which everywhere separates Tocito strata from the underlying Gallup strata (modified after Jennette and Jones 1995).

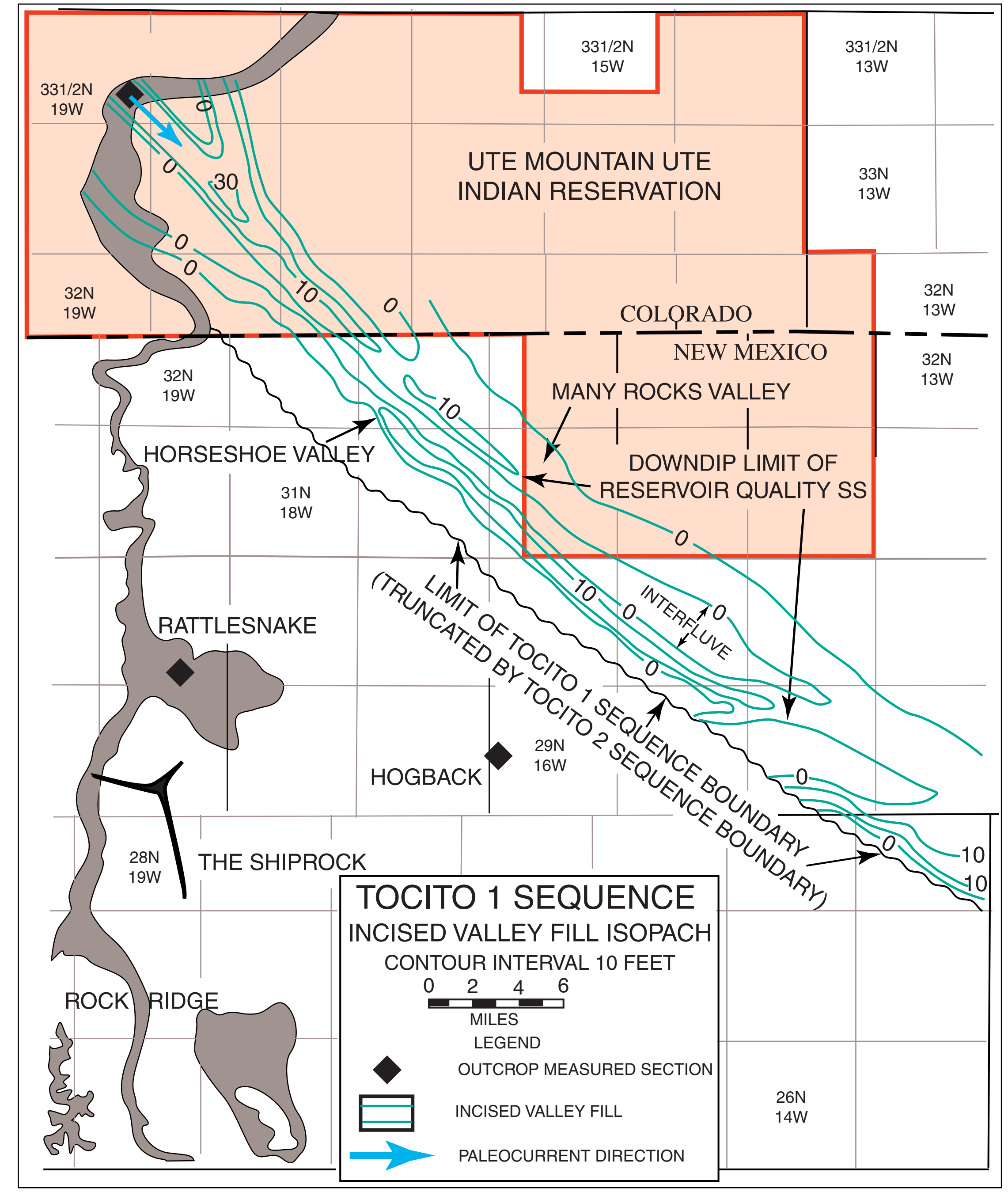

Figure UM-20. Isopach map of the Tocito-1 incised valley system. Two parallel valleys, the Horseshoe and Many Rocks valleys, are separated by a well defined interfluve. Note the position and paleocurrent patterns of the Mounds outcrop locality. Reservoir quality sandstone appears to be present farther down the Horseshoe valley (modified after Jennette and Jones, 1995).

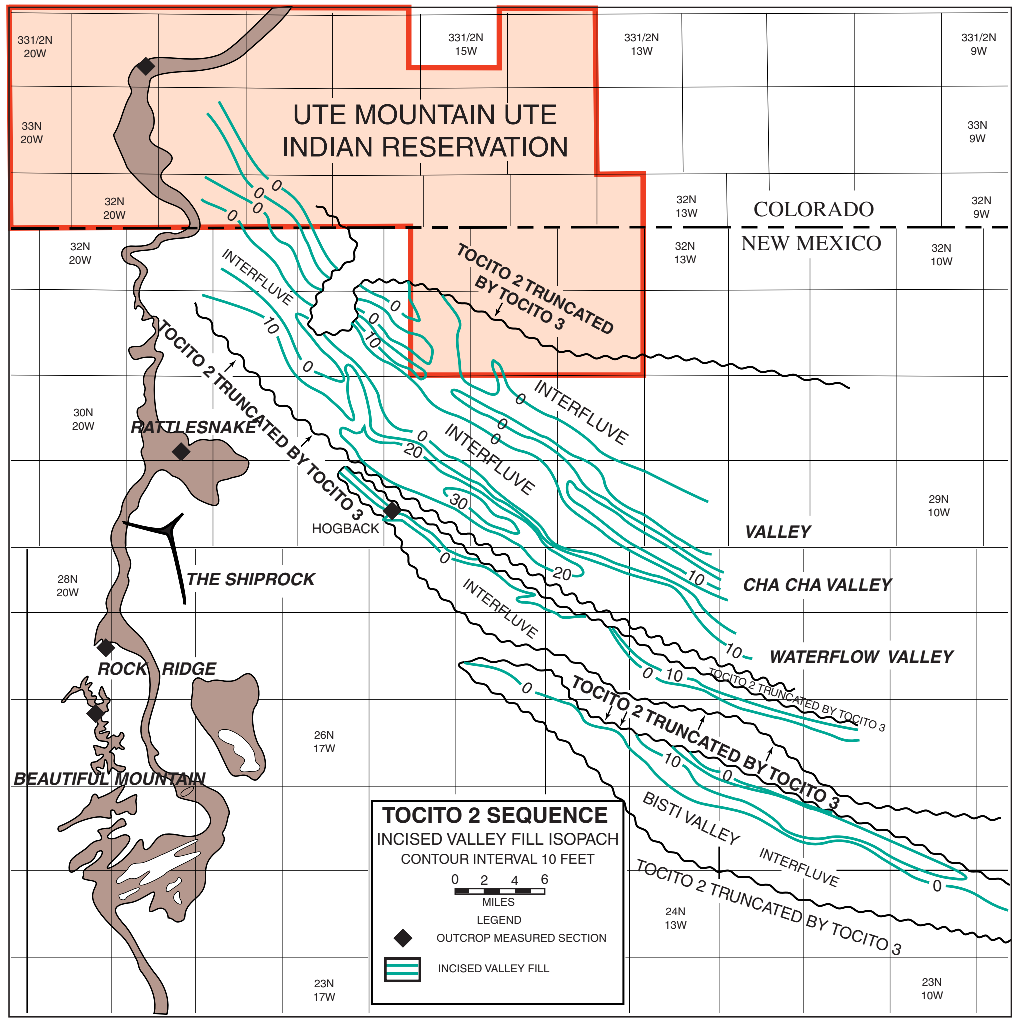

Figure UM-21. Isopach map of the incised valley fill of the Tocito-2 sequence. Four parallel valleys, each separated by interfluves, are evident. The Waterflow Valley contains the thickest interval of sandstone. Note the overall distribution of the lowstand systems tract is more widespread than the Tocito-1 sequence. The Tocito-3 sequence boundary incises and removes the Tocito-2 sequence along the southern margin of the Waterflow Valley and northern margin of the Bisti Valley. These narrow bands of truncation correspond to axial thicks in the Tocito-3 sequence. This erosional relationship has led to a number of hydrocarbon traps in this vicinity (modified after Jennette and Jones, 1995).

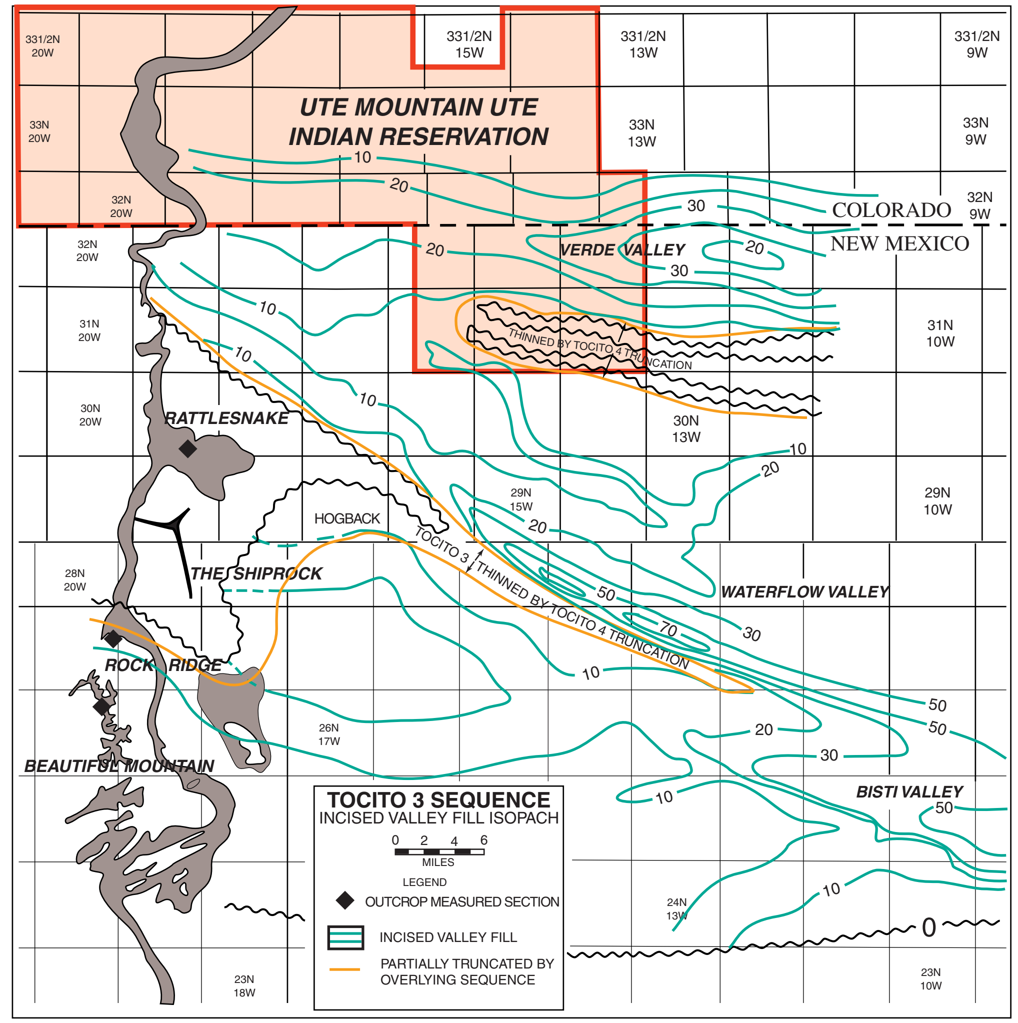

Figure UM-22. Isopach map of the Tocito-3 sequence. The interval mapped is from the Tocito-3 sequence boundary to the Tocito-4 sequence boundary. A wider array of valley shapes is evident: the broad Verde Valley, the deep, V-shaped Waterflow Valley, and the asymmetric Bisti Valley. Note the areas thinned by truncation by the overlying Tocito-4 sequence boundary, particularly along the southern margin of the Waterflow Valley and toward the outcrop area (modified after Jennette and Jones, 1995).

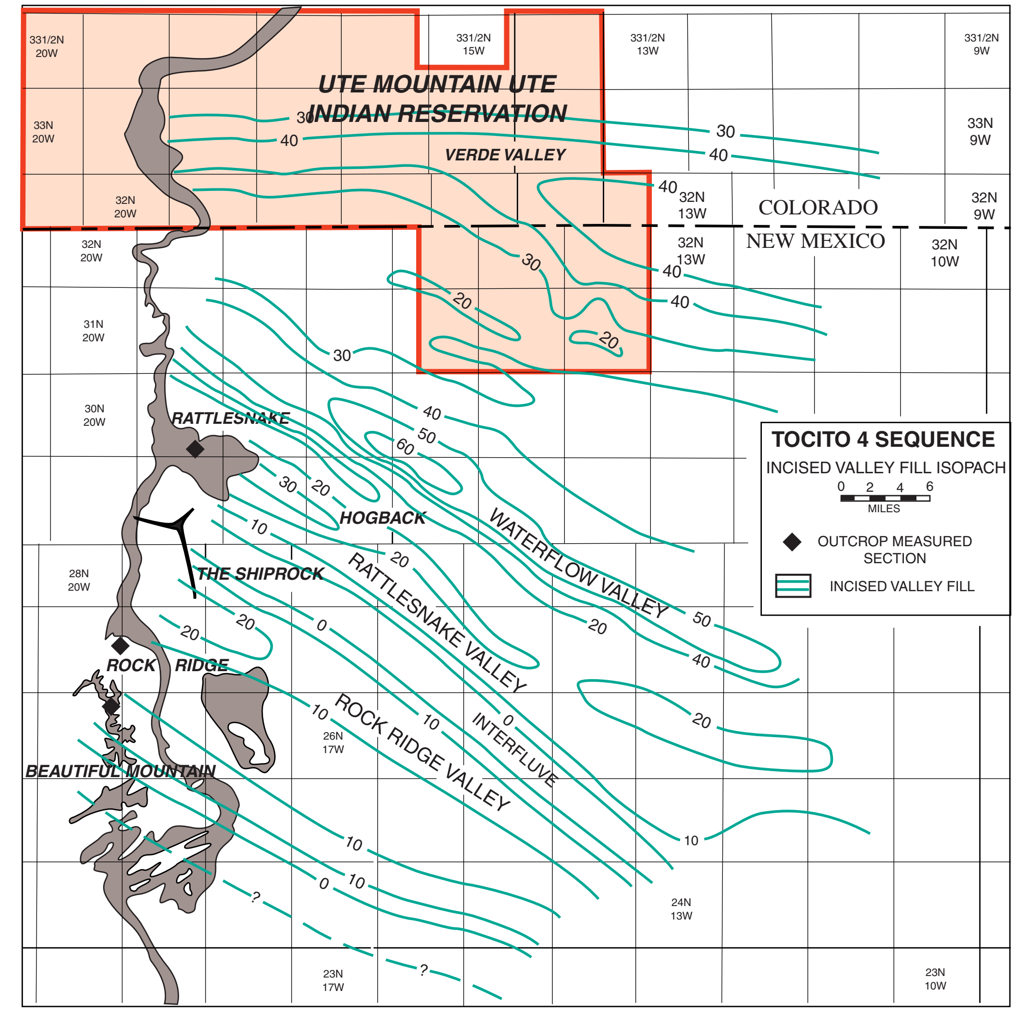

Figure UM-23. Isopach map of the Tocito-4 incised valley-fill sequence. Valley fills make up the bulk of the map and are separated by narrow interfluvial areas. The isopach patterns mapped in the subsurface correspond remarkably well with measured thickness of the Tocito at the outcrop (C.V. Campbell, unpublished Exxon Production Research data). Most of the Tocito in outcrop along Rock Ridge and Beautiful Mountain belongs to the Tocito-4 sequence (modified after Jennette and Jones, 1995).

Analog Fields Near the Reservation

Many Rocks Gallup

(Figs. UM-25 - UM-27)

Location of discovery well: SE ¼, SW ¼, sec 27, T32N, R17W (1962)
Producing formation: Cretaceous Gallup Sandstone
Number of producing wells: 62 (1977)
Production: 9 MOEB (1995)
1,047,270 MCFG (1977)
Gas Characteristics: 1,171 BTU
Oil Characteristics: 40 ° API gravity
Type of drive: Solution gas with limited gas expansion
Average net pay: Upper zone is 5 feet
Lower zone is 7.5 feet
Porosity: 15%
Permeability: 145 mD

Horseshoe Gallup

Location of discovery well: NW ¼, SW ¼, sec 8, T32N, R17W (1961)
Producing formation: Cretaceous Tocito Sandstone
Number of producing wells: 9 (1983)
Production: 40 MOEB (1995)
Oil characteristics: 35 ° API gravity
Type of drive: water
Average net pay: 15 feet
Porosity: 10 -15 %
Permeability: unknown

Cha Cha Gallup

Location of discovery well: NW ¼, SE ¼, sec 17, T28N, R13W
Producing formation: Cretaceous Gallup Sandstone
Number of producing wells: 42 (1977)
Production: 14 MOEB (1995)
17,965,301 MCFG (1977)
Oil characteristics: 41 ° API gravity
Type of drive: Solution Gas
Average net play: Upper zone 10 feet
Lower zone 10 feet
Porosity: 13.5%
Permeability: 57 mD

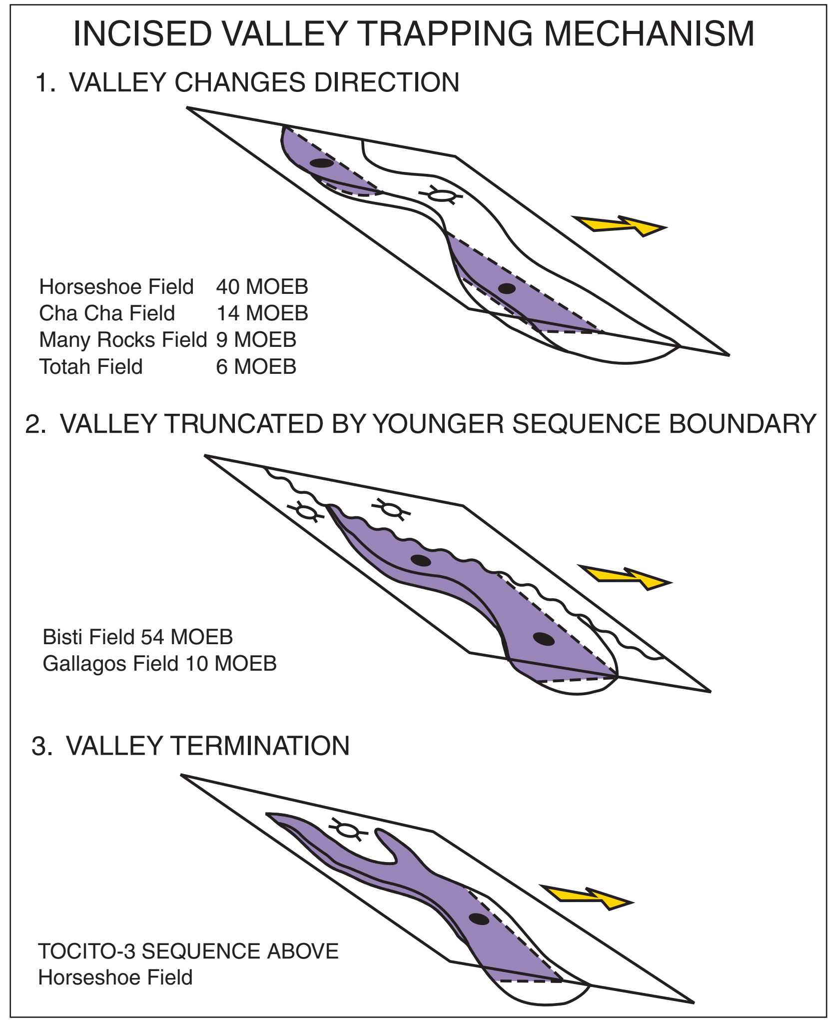

Figure UM-24. Schematic summary of hydrocarbon trapping styles found in the Tocito, stippled patterns indicate the position of oil accumulations (modified after Jennette and Jones, 1995).

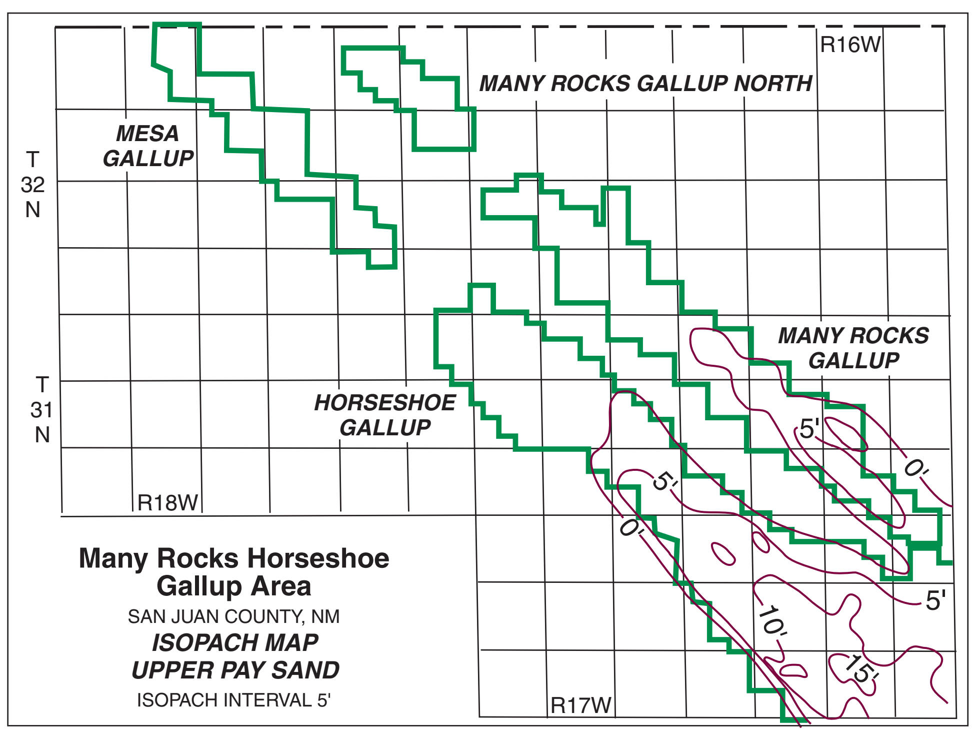

Figure UM-25. Isopach map of the "upper sand pay zone" for the Many Rocks Field (modified after Matheny and Little, 1978).

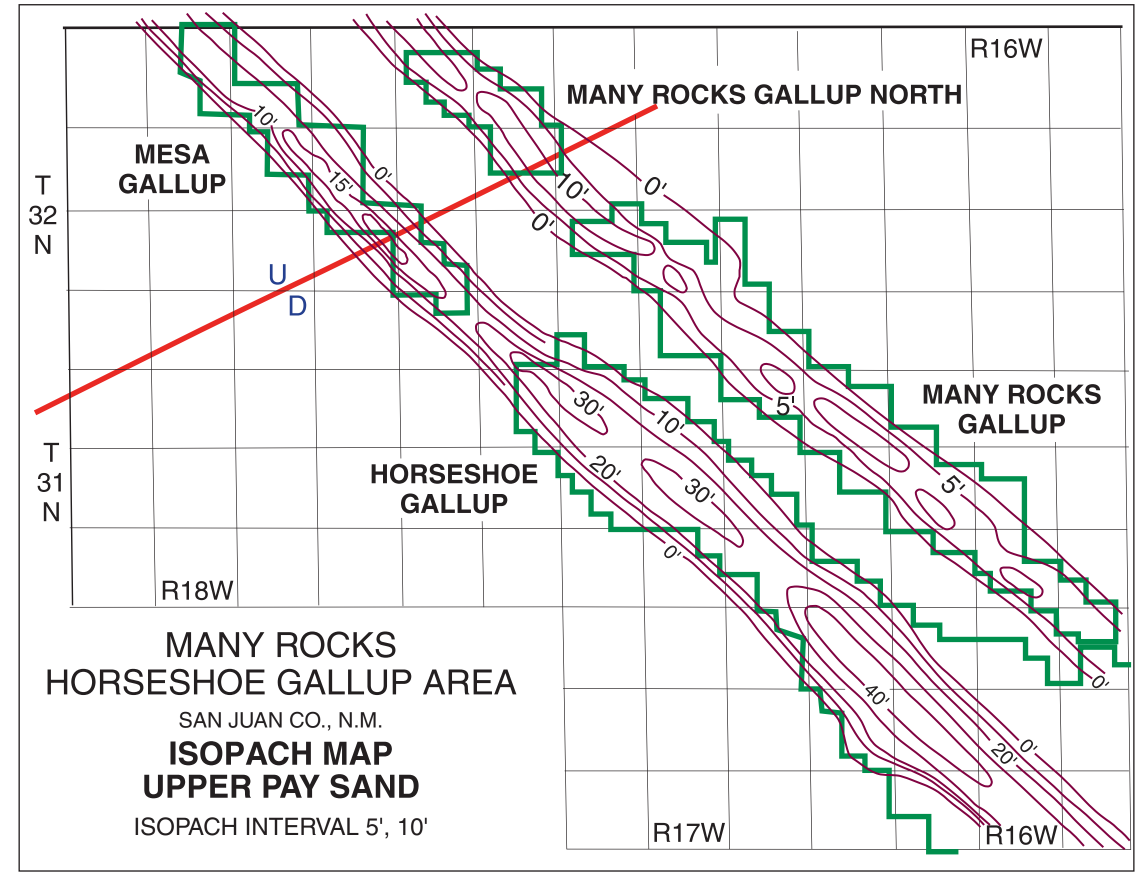

Figure UM-26. Isopach map of the "lower sand pay zone" for the Many Rocks Field (modified after Matheny and Little, 1978).

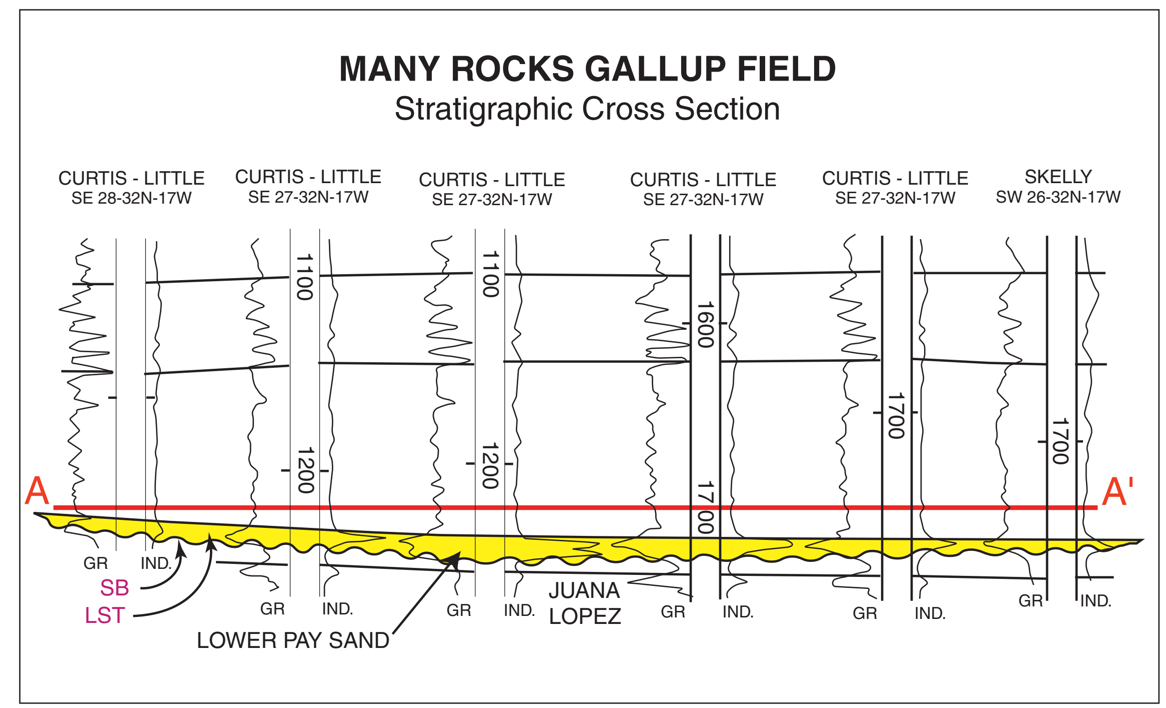

Figure UM-27. Stratigraphic cross section of the "lower sand pay zone" for the Many Rocks Field. Hydrocarbons are trapped in the Tocito- 1 lowstand systems tract (Fig. UM-19) along updip bends in the valley (modified after Jennette and Jones, 1995; Matheny and Little, 1978).